ElectroSpark Deposition studies for gas turbine engine component repair

Hard Chrome Alternatives Team
Canadian Hard Chrome Alternatives Team
Joint Group on Pollution Prevention
Propulsion Environmental Working Group

Replacement of Hard Chrome Plating
Program Review Meeting

20-21 July 2004

Yarrow Resort & Conference Center
1800 Park Avenue
Park City, Utah 84060

Report Documentation Page

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Introductions

Advanced Surfaces and Processes, Inc.

Cornelius, Oregon

Norma Price

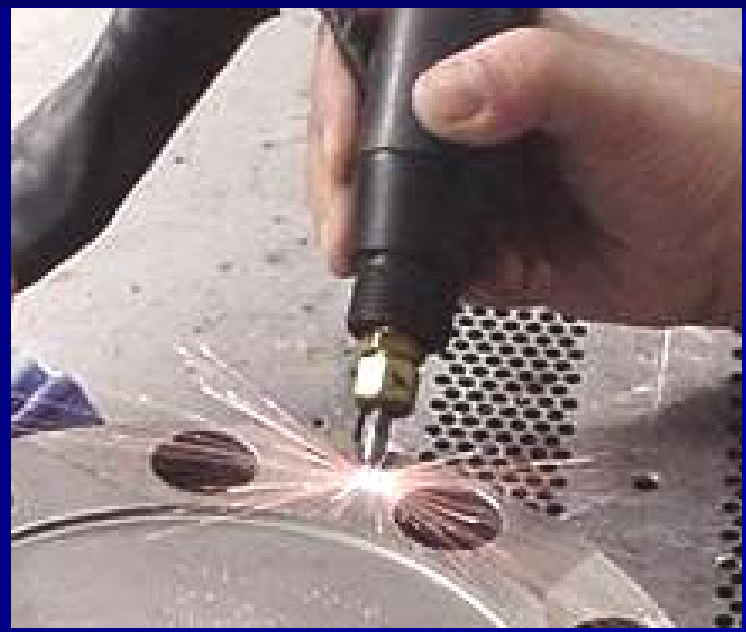
– Mechanical Engineer, Project Manager

John Kelley

– VP R&D

ElectroSpark Deposition (ESD)

The ESD process is comprised of producing an electric arc through a moving electrode energized by a series of capacitors as it is short circuited momentarily with the base material. During the generation of the arc, small particles of the electrode material are melted, accelerated through the arc, impacted against the base metal substrate, solidified rapidly, and build-up occurs incrementally.



ElectroSpark Deposition (ESD)

Advantages

- Metallurgical bond
- Low heat input
- Little or no pre-treatment required
- Little or no post-treatment required
- Environmentally benign
- Portable process and equipment
- Non-line-of-sight applications

Disadvantages

- Low deposition rates

Project Objective

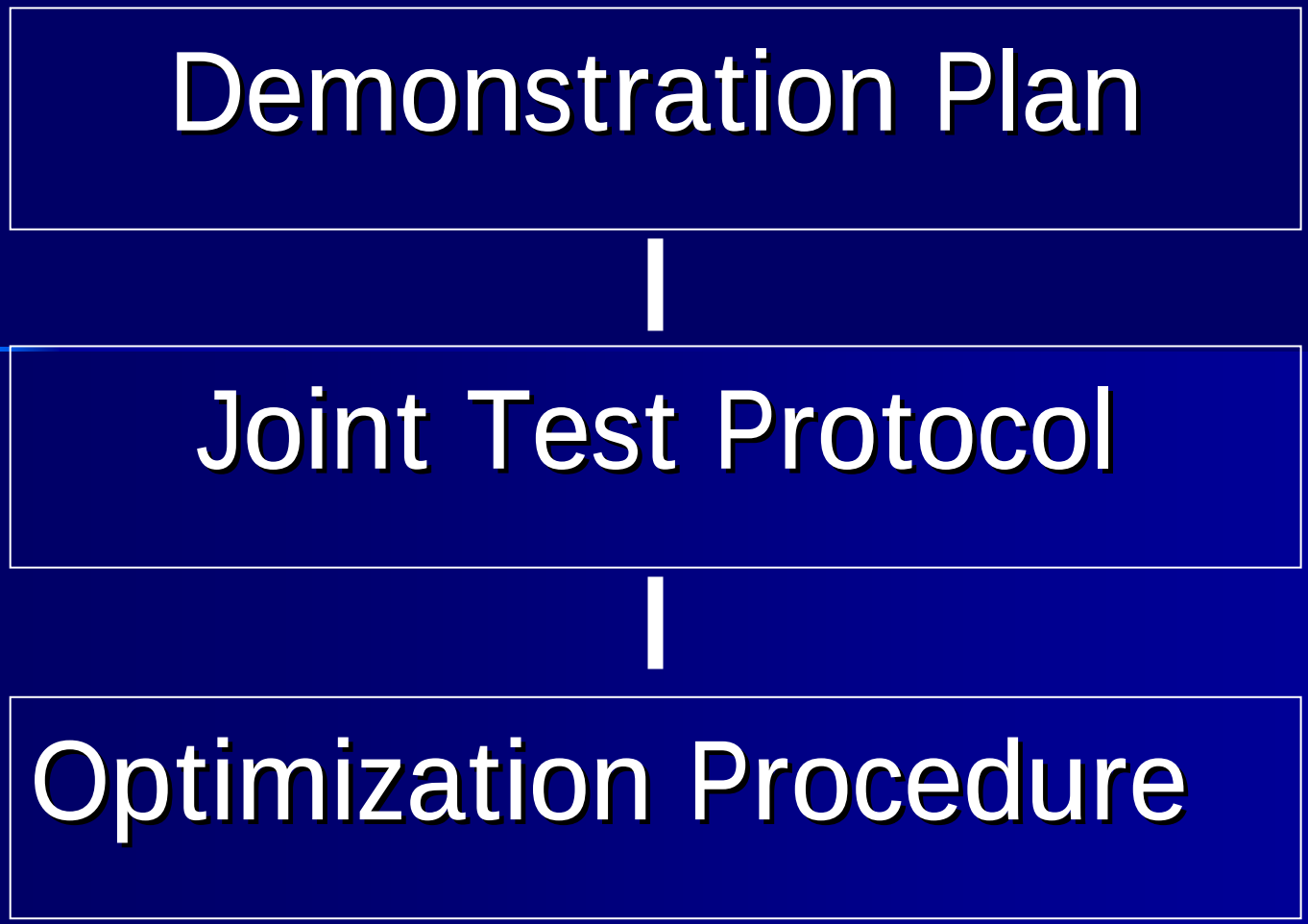
The ESTCP is sponsoring this project to demonstrate and validate ElectroSpark Deposition (ESD) as technically feasible and commercially viable for a production-scale process, and to perform the tests necessary to transition ESD for use on gas turbine engine components.

Stakeholders

- ESTCP - HCAT
- PEWG - ASC/ENV/LPN
- OMI - ASAP
- ONR – Carderock

Participants

- Advanced Surfaces And Processes, Inc. (ASAP)
- Portland State University (PSU)
- Edison Welding Institute (EWI)
- General Electric Aircraft Engines (GEAE)
- Pratt and Whitney (P&W)
- Oklahoma City Air Logistics Center (OC-ALC)
- Rowan Technology Group
- Army Research Lab (ARL)
- Naval Research Laboratory (NRL)
- Metcut Research Inc.



A Demonstration Plan was prepared, which included a JTP. Prior to executing the JTP, the ESD process parameters and technique was optimized.

Project Timeline

Optimization	
Optimization on coupons	Apr 1-Jun 30
Validate results of DOE	Jul 1-Aug 15
Optimize for mechanical properties	Jul 1-Sept 30
JTP	
Fatigue testing	Sept 1-Oct 31
Tensile testing	Sept 1-Oct 31
Wear testing	Sept 1-Oct 31
Corrosion testing	Sept 1-Oct 31
Residual Stress testing	Sept 1-Oct 31
Adhesion Bond testing	Sept 1-Oct 31
JTR and Final Report	Nov 1-Dec 31

Optimization studies for ESD of IN718:
Deposition and Characterization

Optimization

The objective: Identify the optimum ESD parameters to be used on test coupons for the Joint Test Protocol.

An initial DOE will be run for microhardness, deposition rate and microstructure.

Subsequent mechanical tests will be run to optimize material properties such as fatigue and wear properties.

First: Inconel 718 on Inconel 718

Second: 410 stainless steel and Ti-6Al-4V

Finally: Inconel 625, Haynes 188, Hastelloy X, 17-4 PH and Rene 41 or Waspaloy. Also of interest are: Monel 400 and NiCrMo alloys (Alloys 59, 686 and C276), and AerMet 100.

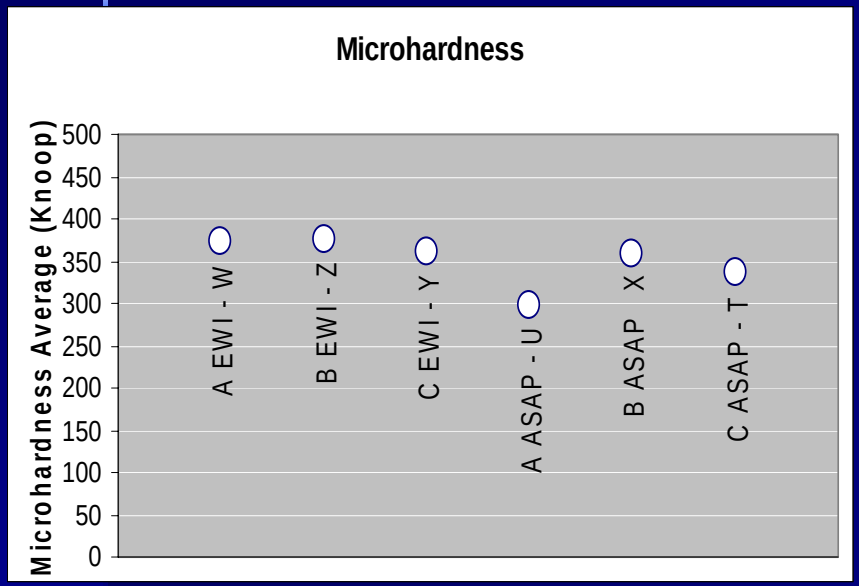
Non-ESD coatings: Electrolytic Hard Chrome (EHC) and Tribaloy 400 or 800.

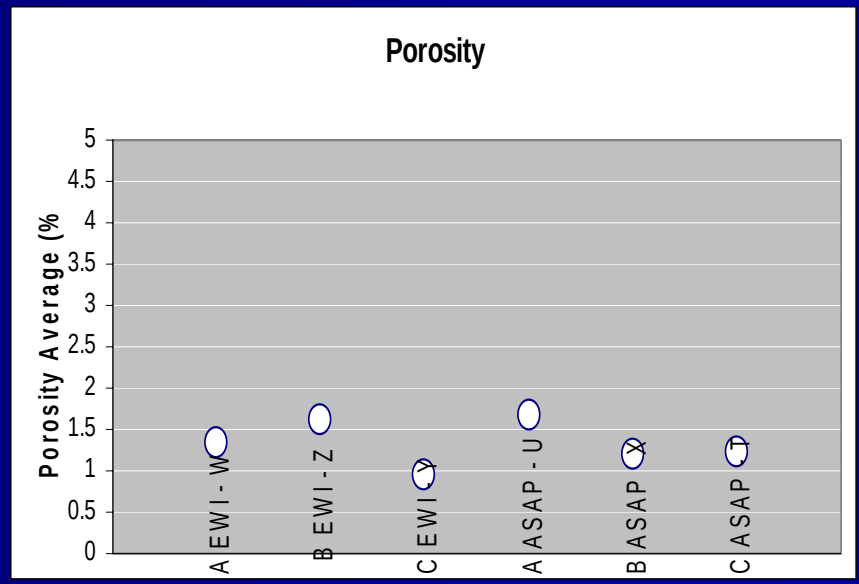
Optimization

Flat coupons (1” x 1” x 0.125”) were used with one “defect” in each specimen. The defect was filled with ESD material.

The DOE specimens were prepared at two locations; EWI in Columbus and ASAP in Portland. This allowed for comparison of specimens prepared by different facilities performing identical ESD processes.

Comparison Coupons





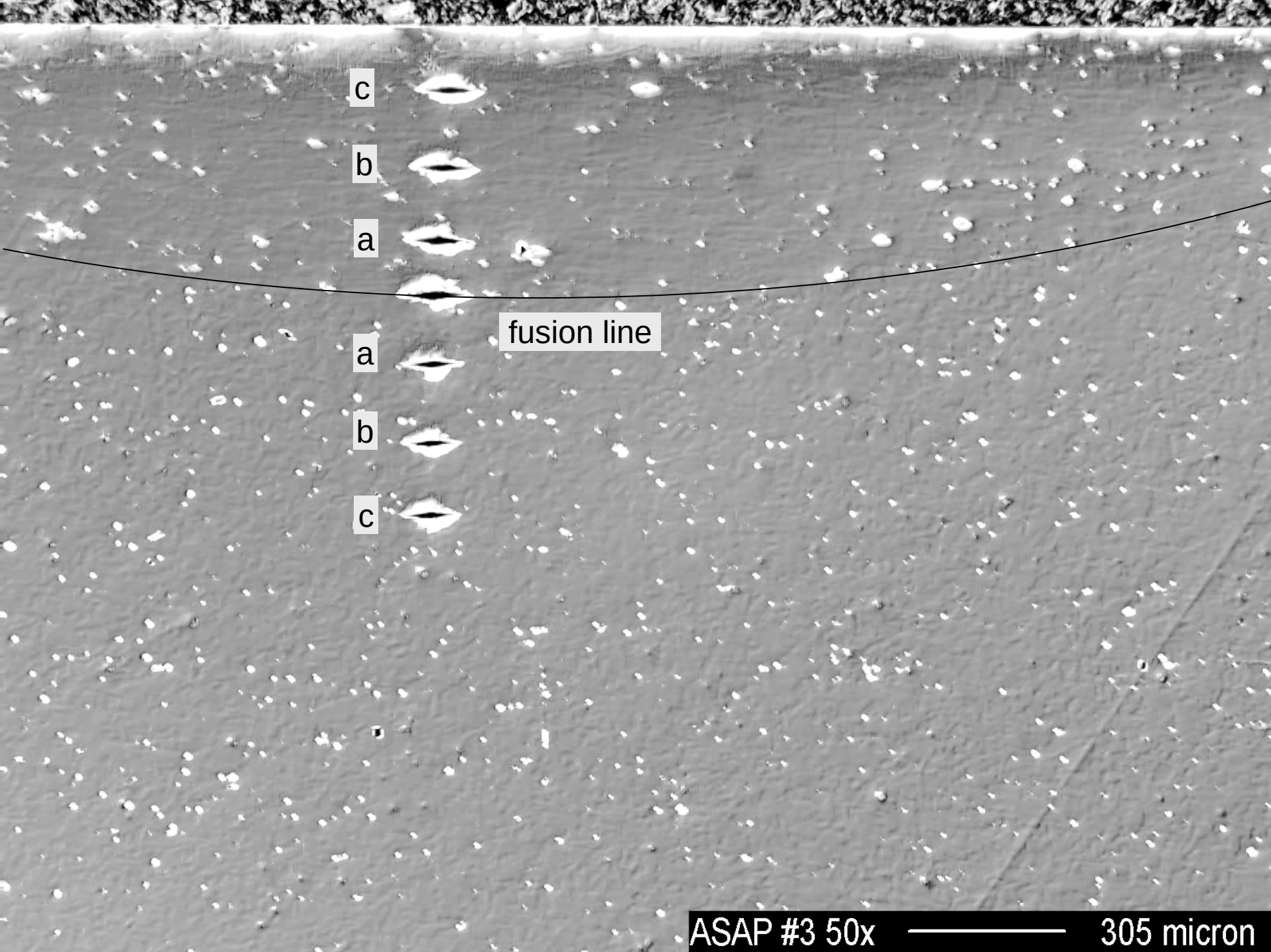
DOE Inputs

Multiple Levels	
Parameter	**Range**
Pulse Rate	300 – 500 Hz, increments of 100
Voltage	80 -130 V, increments of 25
Capacitance	30 – 50 μF, increments of 10
Electrode Revolution speed	800 – 1600 rpm, increments of 400
Electrode Size	0.125 - 0.09375 inch ($^1/_8$, $^1/_{16}$, $^3/_{32}$)
Fixed Levels	
Parameter	**Fixed Value**
Shielding Gas	Argon
Cleaning Frequency	As needed
ESD Surface reshaping (i.e. filing)	As needed
Operating Environment	Room temperature

DOE Outputs

DOE outputs to be recorded
Deposition Rate
Discontinuities
Hardness

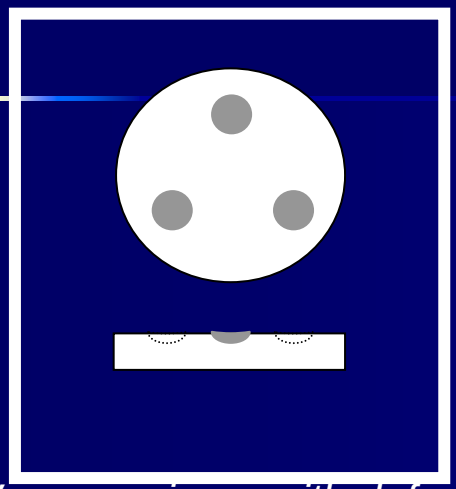
Other outputs to be noted
Current
Surface finish
Microstructure
NDE results


c
b
a
fusion line
a
b
c
ASAP #3 50x
305 micron

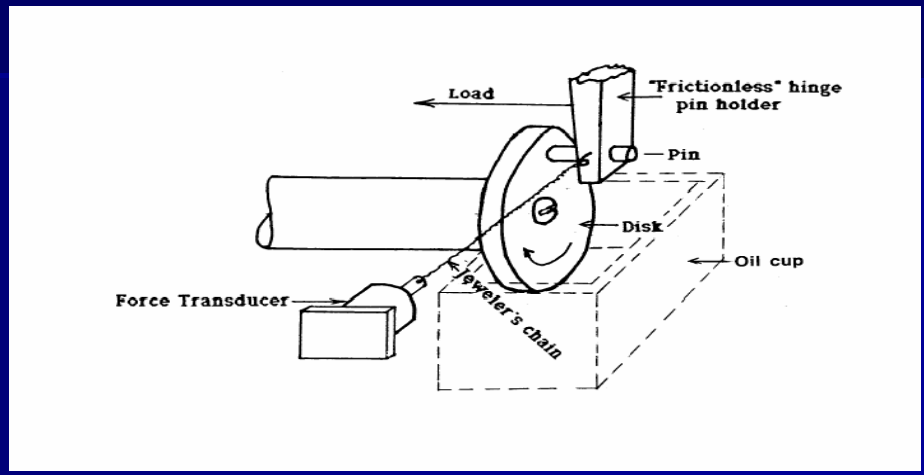
Next Steps

- Validation Coupons
- Pin-on-Disk Wear Testing
- Low Cycle Fatigue Testing

Wear Test



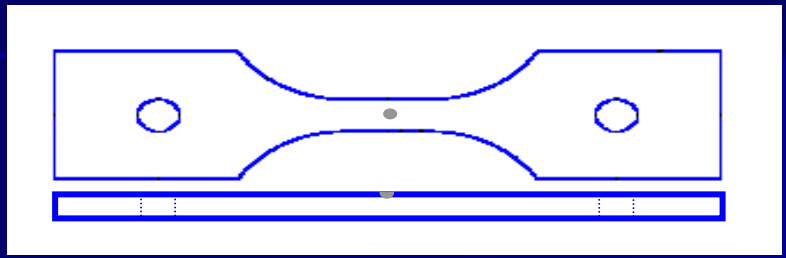
Wear specimen with defects



Pin-on-Disk Wear Testing Apparatus.
Source: http://www.luboron.com/pdf/PinDiskTestDescrip.pdf

Substrate	Flaw type	ESD alloy	Qty	Comments
IN 718	none	none	1	No ESD - baseline
IN 718	Type 1	IN 718	2	Repaired defect, High Dep, 2 Operators
IN 718	Type 1	IN 718	2	Repaired defect, Low Dep, 2 Operators

LCF Test



Fatigue Specimen with defects (defect not to scale)

Substrate	Flaw type	ESD alloy	Qty	Comments
IN 718	none	none	10	No ESD - baseline
IN 718	Type 1	none	6	No ESD – baseline with defect
IN 718	Type 1	IN 718	8	Repaired defect, High Dep, 2 Operators
IN 718	Type 1	IN 718	8	Repaired defect, Low Dep, 2 Operators
IN 718	Type 1	IN 718	8	No defect, High Dep, 2 Operators

Overview of the Joint Test Protocol for gas turbine engine applications

The JTP

Posted on HCAT Website @

http://207.152.96.131/w2g/cgi/kmcgi.exe?O=DIR0000000GPM&V=0

www.HCAT.org

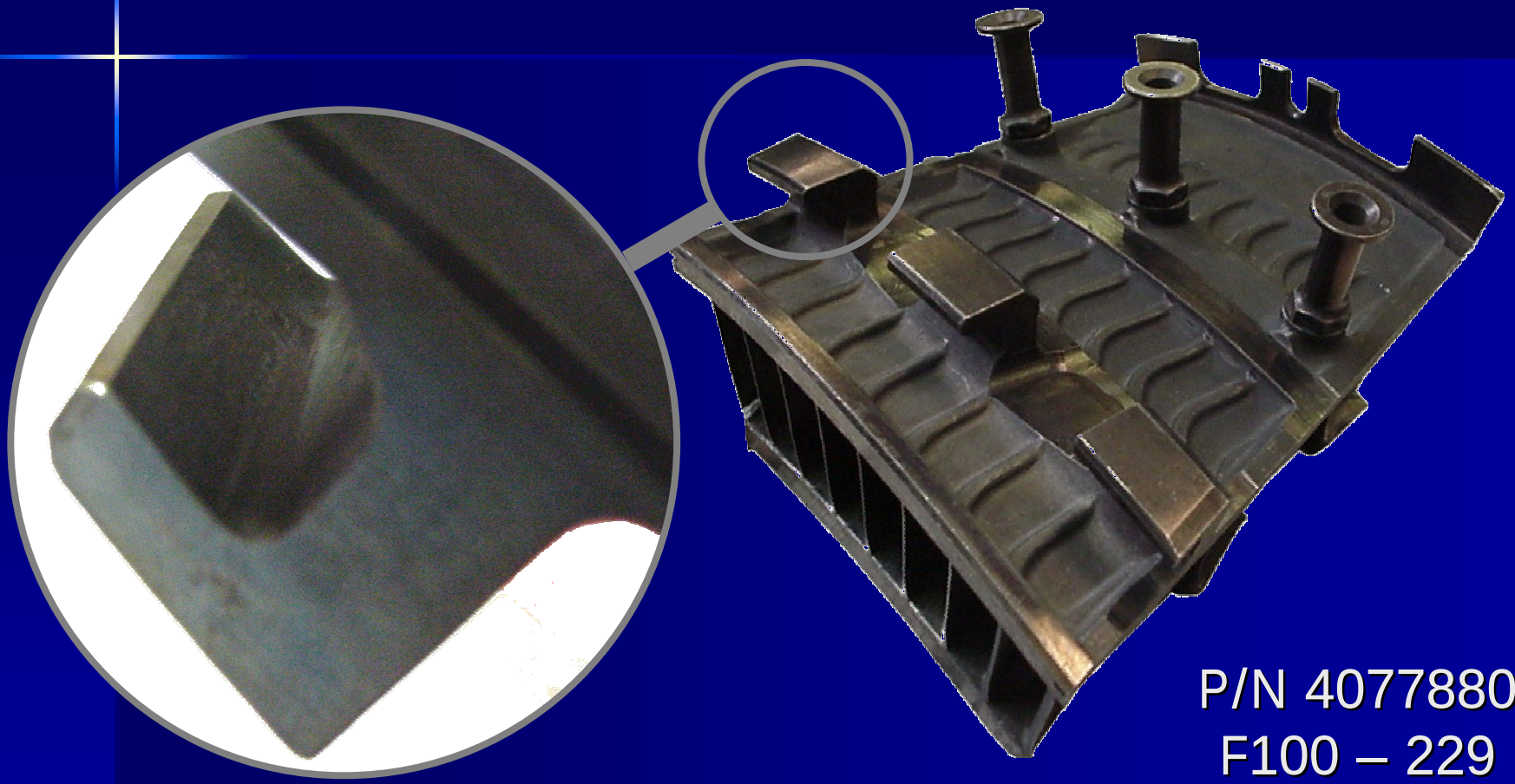
- HCAT Member Workspace
  - Here
    - ESD
      - Log on
        - Test Plans

Joint Test Protocol and Optimization Procedure

Tests

- Low Cycle Fatigue
- Tensile
- Hamilton Sundstrand Wear
- Salt Fog Corrosion
- Residual Stress
- Adhesion Bond

Stator Segment 10-12 Stage



P/N 4077880
F100 – 229
Inconel 718

Stator Segment 10-12 Stage

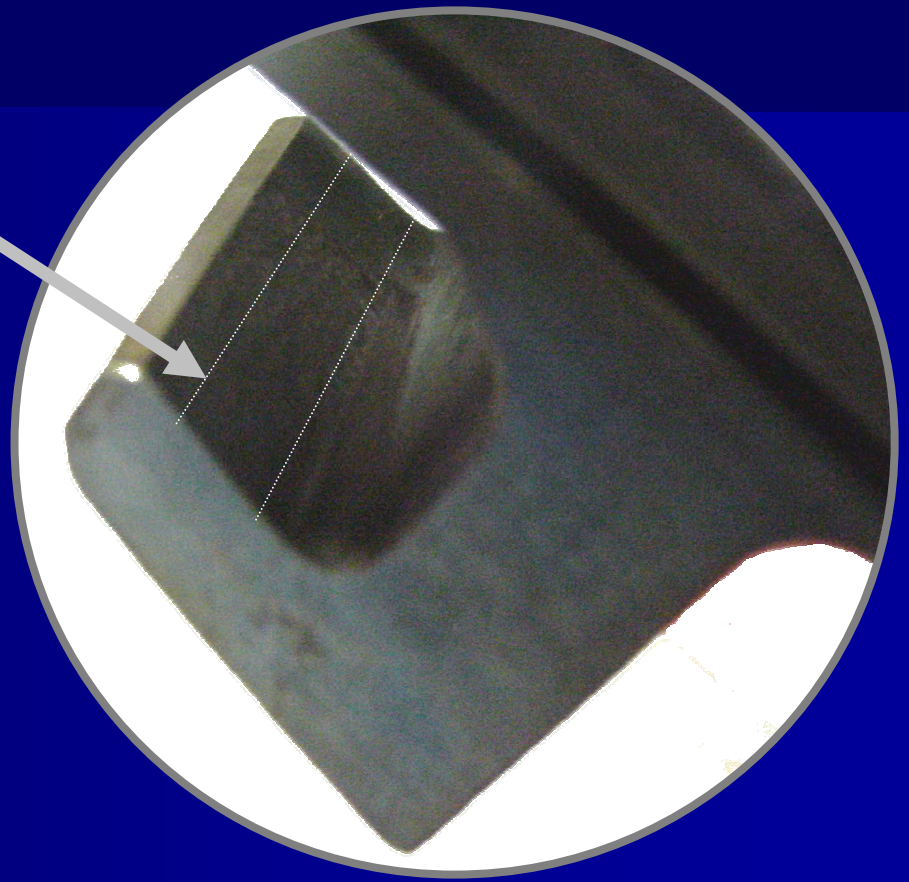
The defect

>0.005” deep wear in hook
non-line-of-sight

Current repair:
Cut off hook,
weld on new,
heat treat part

no repair if the part has met permissible heat treat cycles

Part value:~ $52,000



Project Objective

The ESTCP/PEWG is sponsoring this project to identify, evaluate and qualify applications of the ElectroSpark Deposition (ESD) process for repair of gas turbine engine components.

Materials Selected

IN 718

IN 625

410 SS

Hastelloy X

17-4 PH

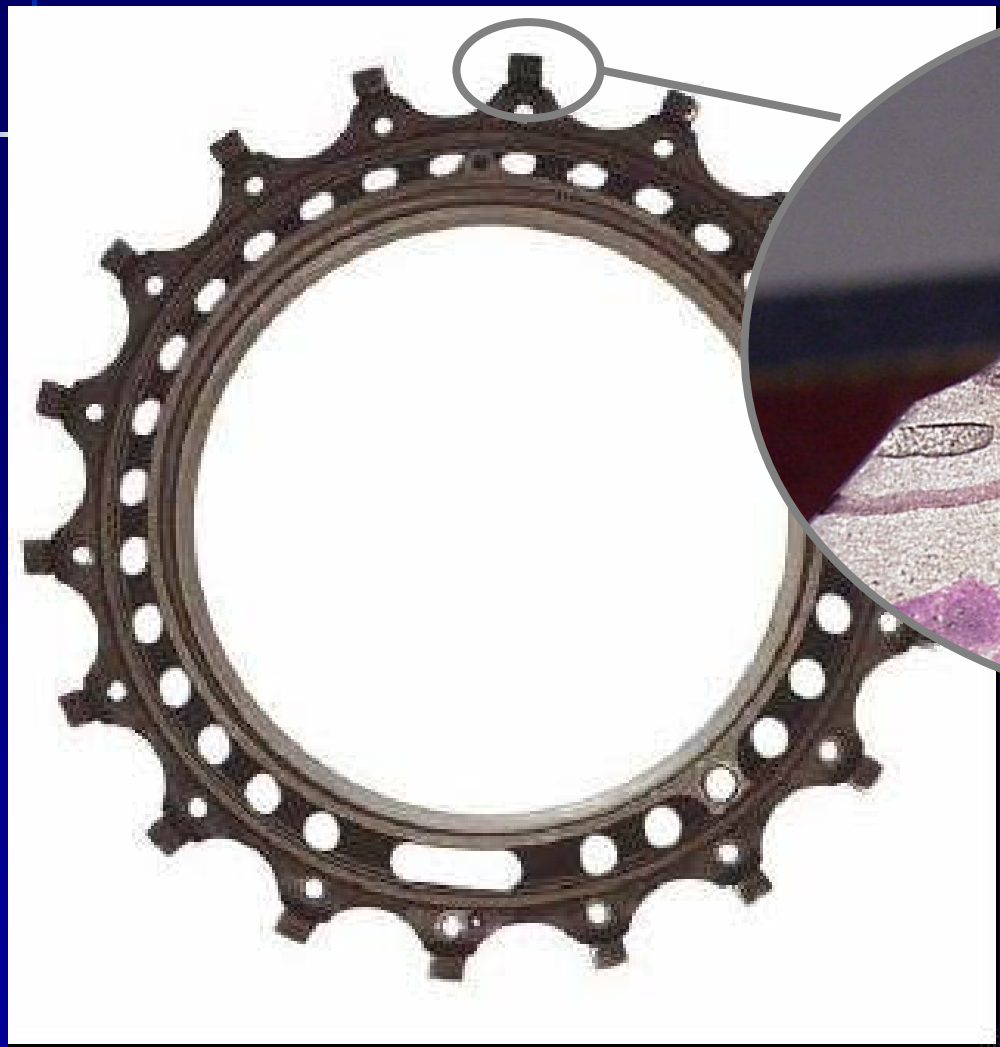
Haynes 188

Tests Performed

- Metallurgical Evaluation
- Microhardness
- Porosity/Density
- Low Cycle Fatigue on IN 718 & 17-4 PH
- Tensile on IN 718

Results available on the HCAT website

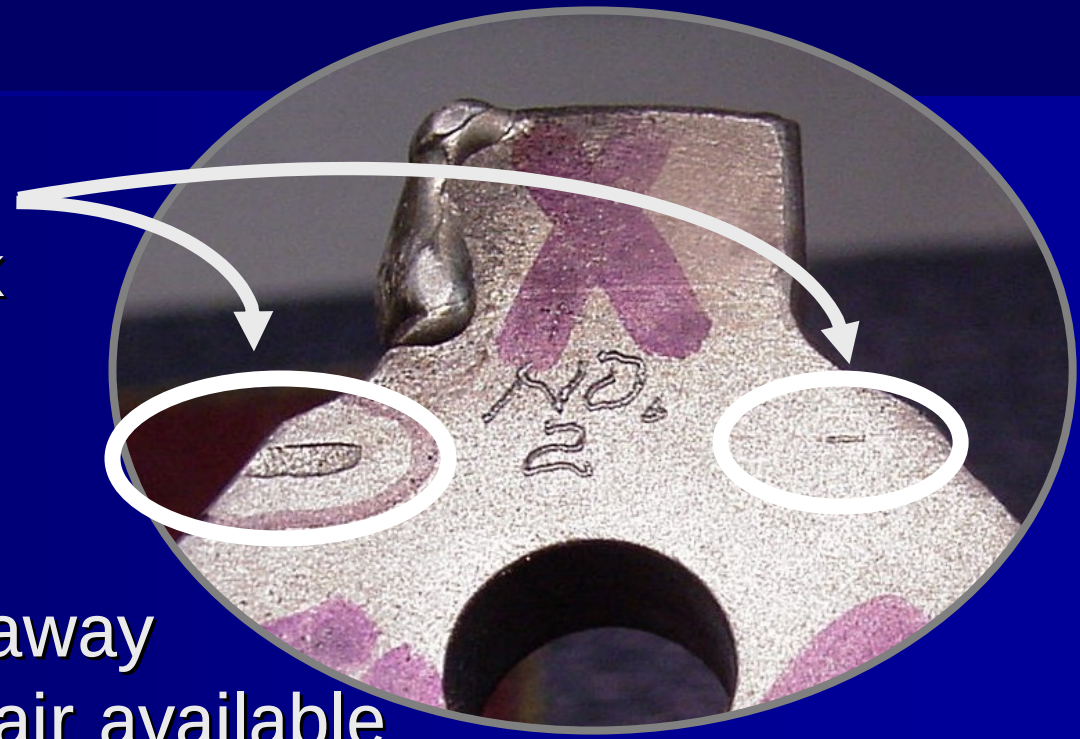
#5 Bearing Housing



P/N 712141
TF 33
AMS 5613
(410 stainless steel)

#5 Bearing Housing

The defect



0.020” to 0.030” wear scars on back face of lug

Current repair:
If < 0.005”, blend away
If > 0.005”, no repair available

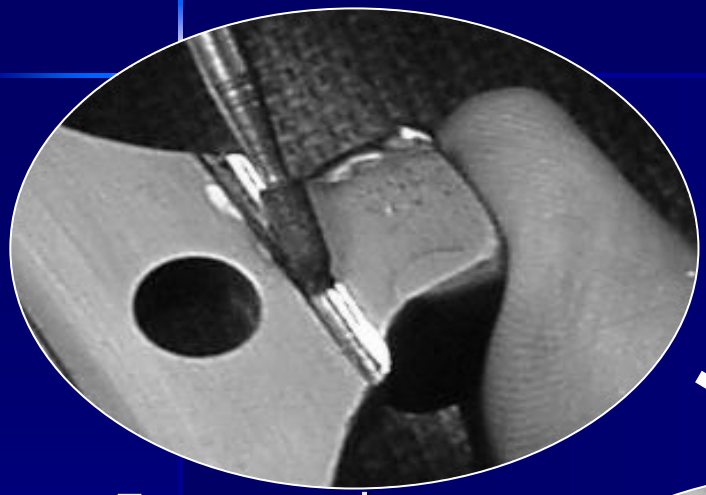
Part value:
~ $1,500 (no longer manufactured)

#5 Bearing Housing
Repair requirements

- Acceptable metallography
- Hardness same as parent material
- Good surface finish

#5 Bearing Housing

Repair procedure



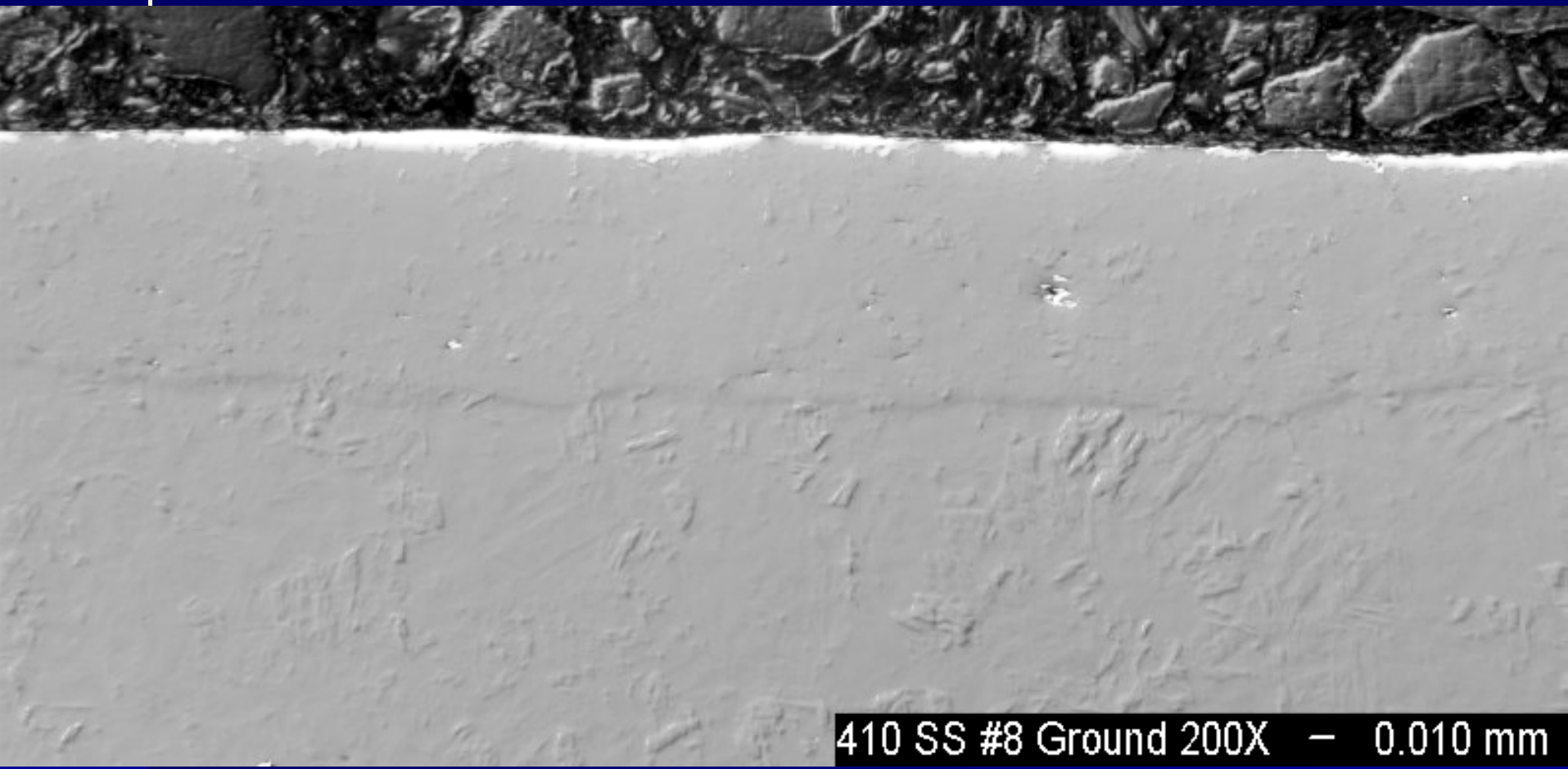
Excavate the defective area

Fill with ESD

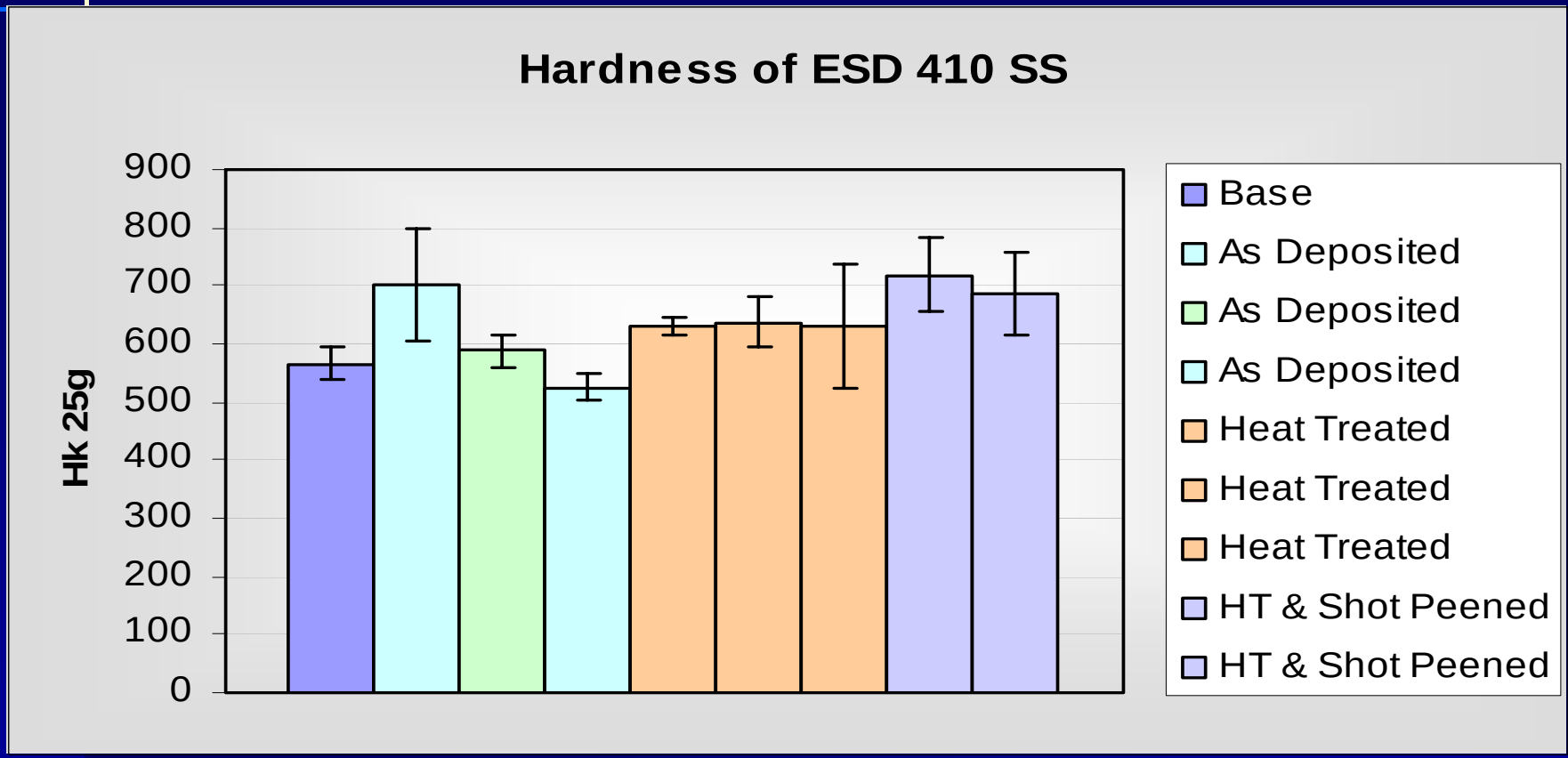
Blend to original surface

#5 Bearing Housing

Metallography



#5 Bearing Housing
Hardness



#5 Bearing Housing
Repair Procedure

- Welding Procedure Specification and hands on demonstration delivered at PEWG, Las Vegas, April 2004.

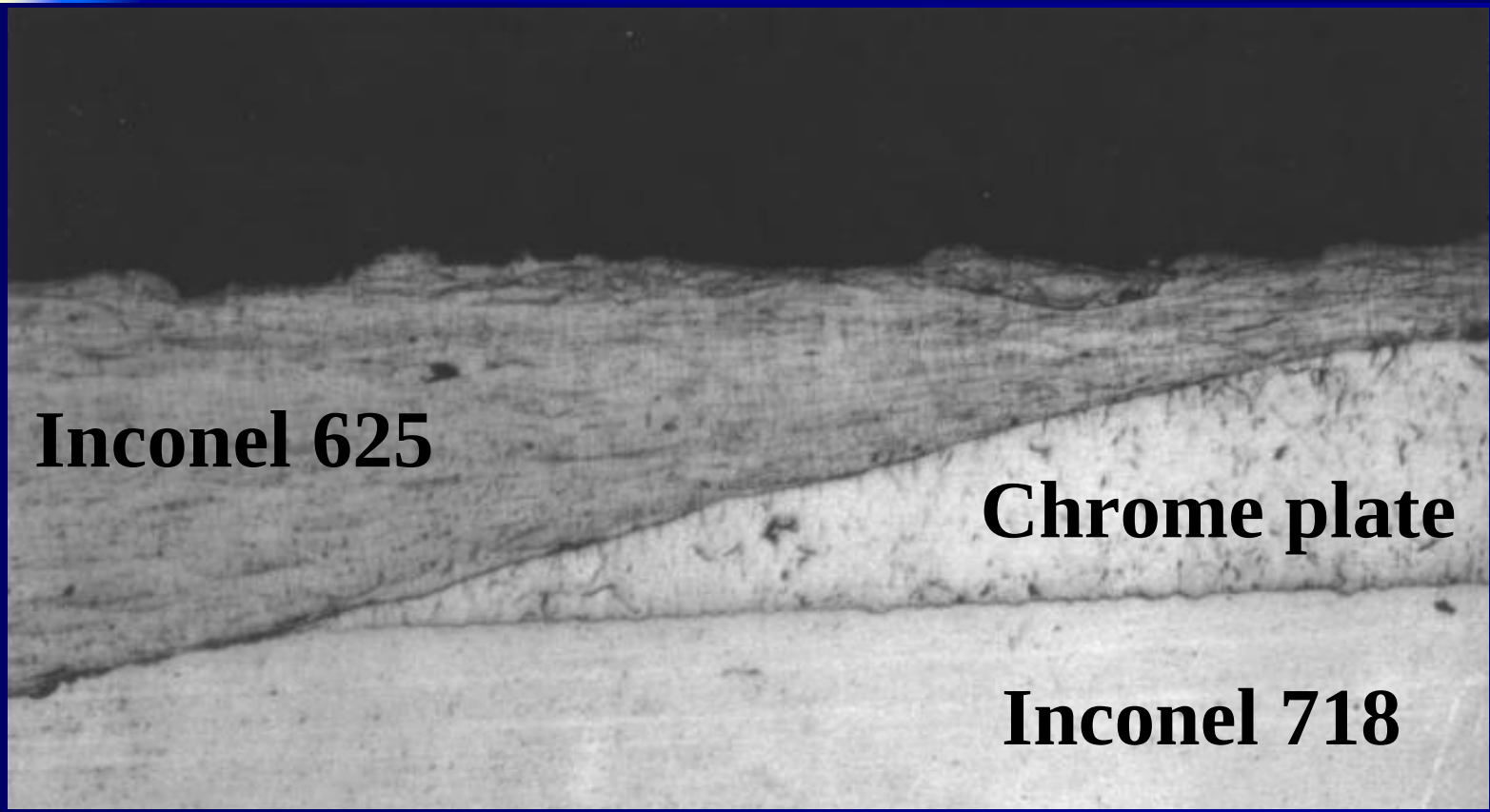
Compressor Rear Shaft

P/N 9103M58G12
TF 39
Inconel 718

The Problems:
Chrome plating on journal incomplete , surface damage

Current repair: Strip and re-plate
Part value: ~ $47,000

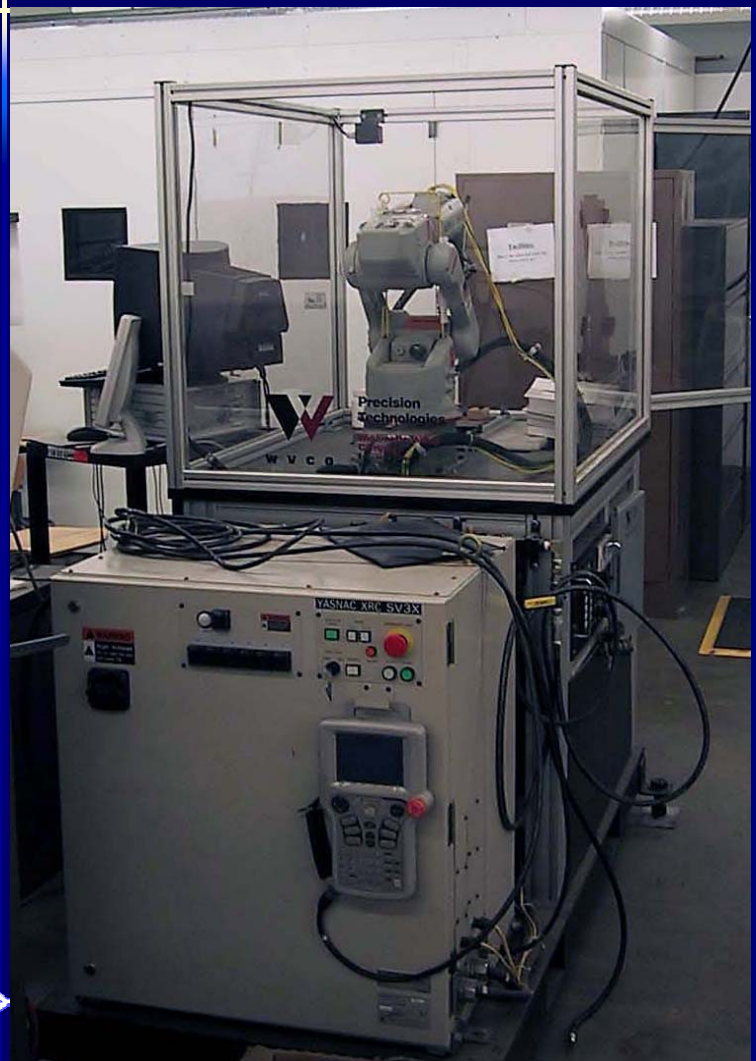
Compressor Rear Shaft
Metallography

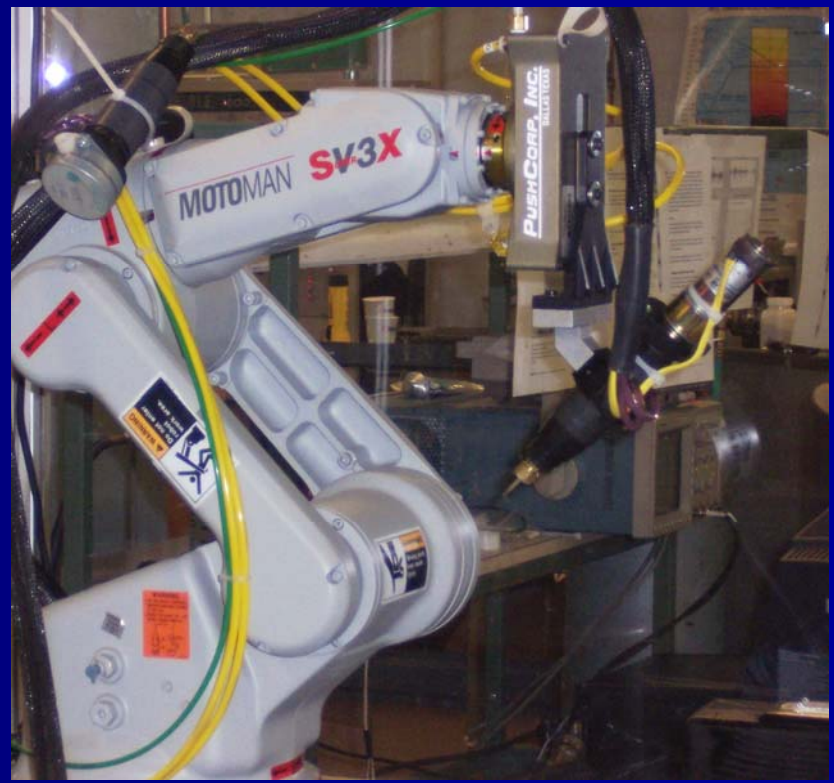


Project Objective

The ESTCP/PEWG is sponsoring this project to demonstrate improvement in ElectroSpark Deposition (ESD) quality and production rates of an ESD repair on alloy 718 through automation and ultrasonic impacting

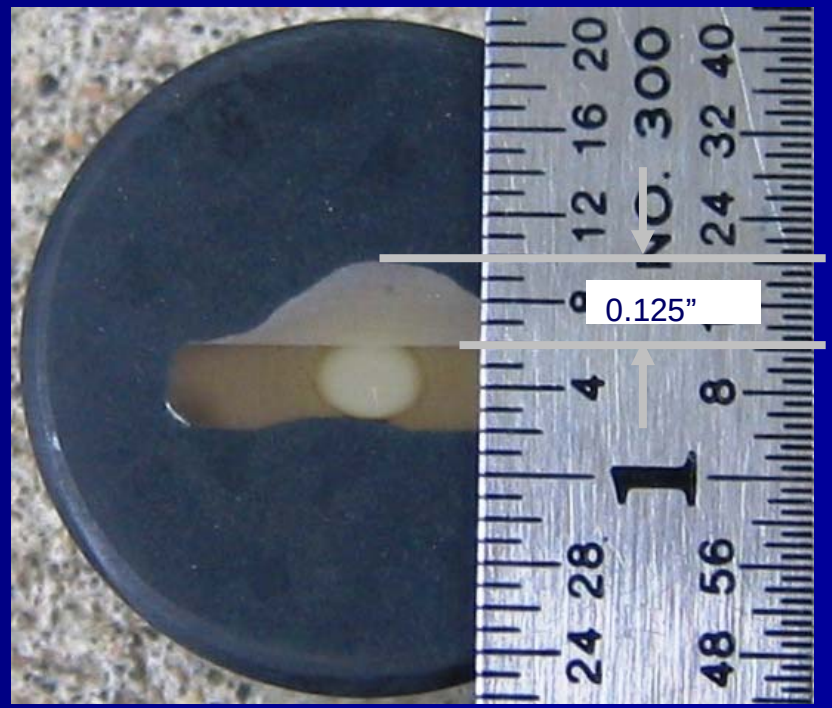
Obtain 5 axis robot system, ultrasonic impact treatment (UIT) system





Develop robotic baseline operating parameters

Baseline for manual ESD of IN718 was obtained from previous work performed by ASAP, for PEWG and ESTCP projects.
Specimens were prepared manually by ASAP to be compared with those prepared by the robot.



Robot ESD Sequence

- 3 conditions: 12 passes, 24 passes, 36 passes
- Argon gas shielding
- Each successive layer will be 90° to the previous
- Each deposit area will be 1” x 1” (3/4” x3/4” deposit)
- Deposition rate for each set will be recorded
- The surface will be manually ground at 12 layer intervals
- Grinding will be substitute by UIT in second sequence
- Each sample will get 2 UIT treatments each after welding.

Remaining Tasks

- Develop baseline UIT parameters
- Combine robotic and UIT technologies
- Conduct productivity test comparisons
- Conduct quality comparisons: automated vs. manual

ElectroSpark Deposition studies for gas turbine engine component repair